

1 I CLAIM:

2  
3 1. In the method of consolidating a body in  
4 any of initially powdered, sintered, fibrous, sponge,  
5 or other form capable of compaction, that includes the  
6 steps:

7 a) providing flowable pressure transmission  
8 particles having carbonaceous and ceramic composition  
9 or compositions,

10 b) heating said particles to elevated  
11 temperature,

12 c) locating said heated particles in a bed,

13 d) positioning said body at said bed, to  
14 receive pressure transmission,

15 e) effecting pressurization of said bed to  
16 cause pressure transmission via said particles to said  
17 body, thereby to compact and consolidate the body into  
18 desired shape, increasing its density;

19 f) the body consisting essentially of one  
20 or more metals selected from the following group:  
21 tungsten, rhenium, uranium, tantalum, platinum, copper,  
22 gold, hafnium, molybdenum, titanium, zirconium and  
23 aluminum;

24 g) said consolidated body having, along a  
25 body dimension, one of the following characteristics:

- 1                   i)    decreasing strength  
2                   ii) increasing ductility  
3                   iii) decreasing strength, and increasing  
4                   ductility.

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7                   2.    The method of claim 1 wherein the body  
8 has varying metallic composition along said dimension.

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11                  3.    The method of claim 1 wherein said  
12 varying metallic composition is characterized by a  
13 series of zones, the metal of each zone having a  
14 characteristic composition which differs from that of  
15 an adjacent zone or zones.

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18                  4.    The method of claim 3 wherein the metals  
19 in at least two successive zones consist substantially  
20 of tantalum, and tantalum consolidated with a metal or  
21 metals selected from the group tungsten, rhenium,  
22 uranium, tantalum, platinum, copper, gold, hafnium,  
23 molybdenum, titanium, zirconium and aluminum.

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1           5. The method of claim 1 wherein said body  
2 consists of powders of metals that have been initially  
3 combined and compressed into body form, at pressure  
4 exceeding 20,000 pounds per square inch, prior to said  
5 step e) pressurization.

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8           6. The method of claim 5 wherein at least  
9 part of said body has one of the following forms:

- 10                   i) cone  
11                   ii) lens  
12                   iii) cylinder  
13                   iv) cylinder and cone combination  
14                   v) cylinder and lens combination.

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17           7. The method of claim 5 including pre-  
18 heating said body to temperature in excess of 900°C,  
19 subsequent to said initial combining and compressing  
20 and prior to said pressurization.

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23           8. The method of claim 5 including  
24 effecting said initial combining and compressing at  
25 ambient temperature.

1           9.    The method of claim 5 including  
2 providing an elastomeric container, positioning said  
3 powders in said container, and effecting said initial  
4 compressing by compressing said container.

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7           10.   The method of claim 9 including  
8 evacuating gases from said container, prior to said  
9 initial compressing thereof.

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12           11.   The method of claim 10 including sealing  
13 of said container after evacuating gases therefrom.

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16           12.   The method of claim 11 wherein said  
17 initial compressing is effected to compress the body to  
18 about 60% of body theoretical density.

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21           13.   The method of claim 1 wherein said  
22 pressurization is effected to form the body into  
23 generally conical shape.

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1           14. The method of claim 1 including  
2 effecting said initial compressing to form the body  
3 into generally cylindrical shape, with taper at one  
4 end.

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7           15. The method of claim 14 wherein said  
8 pressurization is carried out to reduce the body size  
9 while maintaining body generally cylindrical shape with  
10 taper at one end.

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13           16. The method of claim 5 wherein the  
14 powders at one zone of the body consist essentially of  
15 tantalum particles coated with substance or substances  
16 selected from the group that include tungsten, rhenium,  
17 uranium, platinum, copper, gold, hafnium, molybdenum,  
18 titanium, zirconium and aluminum.

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21           17. The method of claim 16 wherein the  
22 weight percent of said substance or substances is about  
23 16% of the overall weight of the total powder.

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1           18. The consolidated body produced by the  
2 method of claim 1.

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5           19. The method of claim 1 wherein said  
6 particles are generally spheroidal and consist of  
7 graphite, and/or graphite and ceramic composite.

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10           20. The method of claim 1 wherein said body  
11 in said bed, prior to said step e) is at a temperature  
12 between about 200°C. and 1,800°C.

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15           21. The method of claim 1 wherein said body  
16 is positioned in said bed to be surrounded by said  
17 particulate, the bed consisting substantially entirely  
18 of particles in the form of graphite and/or  
19 graphite/ceramic beads.

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22           22. The method of claim 15 wherein said bed  
23 contains sufficient of said flowable particles as to  
24 remain essentially free of agglomeration during said  
25 (e) step.

1           23. The method of claim 1 wherein said bed  
2 consists essentially of one of the following  
3 particulates:

- 4           i) graphite  
5           ii) ceramic  
6           iii) graphite and ceramic.

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9           24. The method of claim 23 wherein the  
10 particle mesh size is between 50 and 240.

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13           25. The method of consolidating metal powder  
14 to form an object, that includes:

15           a) pressing said powder into a preform, and  
16 preheating the preform to elevated temperature,

17           b) providing flowable pressure transmitting  
18 particles and heating said particles, and providing a  
19 bed of said flowable and heated pressure transmitting  
20 particles,

21           c) positioning the preform in such relation  
22 to the bed that the particles substantially encompass  
23 the preform,

24           d) and pressurizing said bed to compress  
25 said particles and cause pressure transmission via the

1 particles to the preform, thereby to consolidate the  
2 preform into a desired object shape,

3 e) the preform consisting of one or more  
4 metals selected from the following group: tungsten,  
5 rhenium, uranium, tantalum, platinum, copper, gold,  
6 hafnium, molybdenum, titanium, zirconium and aluminum.

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9 26. The method of claim 25 wherein the  
10 powder at one zone of the body consists of tantalum  
11 particles coated with substances selected from the  
12 group that includes tungsten, rhenium, uranium,  
13 platinum, copper, gold, hafnium, molybdenum, titanium,  
14 zirconium and aluminum.

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17 27. The method of claim 26 wherein the  
18 weight percent of said substances is about 16% of the  
19 overall weight of the total powder.

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22 28. The method of claim 25 wherein said  
23 pressurization is effected at levels greater than about  
24 20,000 psi for a time interval of less than about 30  
25 seconds.

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1                   29. The method that includes  
 2                   a) providing particles to be used in  
 3 pressure consolidation of a powdered preform;  
 4                   b) heating said particles,  
 5                   c) and pressurizing the heated particles to  
 6 effect said consolidation,  
 7                   d) said preform consisting essentially of  
 8 metallic particles selected from the following group:  
 9 tungsten, rhenium, uranium, tantalum, platinum, copper,  
 10 gold, hafnium, molybdenum, titanium, zirconium and  
 11 aluminum.

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 14                   30. The method of claim 29 wherein the  
 15 particles include tantalum which constitutes more than  
 16 50% of the overall weight of the preform.

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 19                   31. The method of claim 29 wherein the  
 20 preform initial powder consists of tantalum particles  
 21 on which the metallic particles are coated.

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1           32. A metallic body which has been  
2 compressed and consolidated from an initial powder  
3 metal form to a highly densified form, the body  
4 consisting of at least two metals, the proportions of  
5 which vary along a body dimension, one of said metals  
6 being tantalum.

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9           33. The body of claim 32 wherein the body  
10 consists of at least four metals.

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13           34. The body of claim 33 wherein said metals  
14 are selected from the group that includes tungsten,  
15 rhenium, uranium, tantalum, platinum, copper, gold,  
16 hafnium, molybdenum, titanium, zirconium and aluminum.

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19           35. The body of claim 32 wherein the body is  
20 elongated and has a tapered nose portion, there being a  
21 second body portion along said dimension, the body  
22 consisting of at least two metals,  $M_1$  and  $M_2$ , the  
23 proportions of  $M_1$  and  $M_2$  in said body nose portion and  
24 second body portion being different.

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1           36. The body of claim 35 wherein the metal  
2  $M_1$  is tantalum, the proportion of tantalum in said nose  
3 portion being greater than the proportion of tantalum  
4 in said second body portion.

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7           37. The body of claim 36 wherein the body  
8 has third and fourth body portions along said  
9 dimension, the proportion of tantalum in said second  
10 body portion exceeding the proportion of tantalum in  
11 said third body portion, and the proportion of tantalum  
12 in said third body portion exceeding the proportion of  
13 tantalum in said fourth body portion.

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16           38. The body of claim 32 wherein the body  
17 has first and second ends, the consolidated metal at  
18 the first end having higher density than the metal at  
19 the second end.

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22           39. The body of claim 38 wherein the metal  
23 at the first end consists primarily of tantalum, and  
24 the metal at the second end consists primarily of  $M_1$ ,  
25  $M_2$ , or  $M_x$ .

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1 40. A pressure consolidated powdered metal  
2 product wherein the powdered metal is distributed in  
3 successive layers, each layer having a different weight  
4 percentage of consolidated powdered metals, at least  
5 one of the powdered metals being tantalum.

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8 41. The body of claim 32 which has  
9 decreasing strength or ductility in each of two body  
10 dimensions.

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13 42. The body of claim 41 wherein said two  
14 dimensions are length and thickness.

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17 43. The body of claim 41 wherein said two  
18 dimensions are longitudinal and lateral.

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21 44. The body of claim 41 wherein said body  
22 tapers toward a top zone, the body ductility and/or  
23 strength being greatest at said top zone.

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1 45. The body of claim 41 wherein said body  
2 comprises a conical shell.

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5 46. The body of claim 41 which has a  
6 cylindrical section and a tapered section at one end of  
7 the cylindrical section.

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9  
10 47. The method of claim 32 wherein the  
11 consolidated tantalum has <111> texture of less than  
12 about 2.8X random.

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